

# Visiting the NASA Centers, and Locations of Historic Rockets & Spacecraft

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# **Introduction**

This book discusses the various NASA Centers across the United States, and presents what can be seen at each. Each has a specialty, and each generally has a visitor's center worth visiting. The guide also mentions nearby facilities of interest, such as the Smithsonian's two Air-and-Space Museum facilities. We will cover all of the manned (U.S.) flight hardware still in existence, including some related aircraft such as the X-15 and the Shuttle Carrier Aircraft. Not all of these projects saw flight, but some boiler plate or test models survive. There is more stuff rusting away outside storage buildings at NASA Centers or at Aerospace Contractor's facilities. During work on this book, two additional manned capsules were located.

Before you visit any of the sites, look up the site's website for hours and days of operation, fee, if any, and restrictions (such as regarding pets). Enjoy your trip. It's almost impossible not to, from the hard core space junkie to the casual visitor, the immensity of these projects is overwhelming.

## **Author**

The author received a Bachelors degree in Electrical Engineering from Carnegie-Mellon University, and Masters Degrees in Physics and Computer Science from the Johns Hopkins University.

He was glued to the black & white tv for the launch of the Vanguard, the U. S.'s first satellite, through the Apollo missions.

He began his career in Aerospace with Fairchild Industries on the ATS-6 (Applications Technology Satellite-6), program, a communication satellite that developed much of the technology for the TDRSS (Tracking and Data Relay Satellite System). At Fairchild, Mr. Stakem made the amazing discovery that computers were put onboard the spacecraft. He quickly made himself the expert on their support. He followed the ATS-6 Program through

its operation phase, and worked on other projects at NASA's Goddard Space Flight Center including the Hubble Space Telescope, the International Ultraviolet Explorer (IUE), the Solar Maximum Mission (SMM), some of the Landsat missions, and others. He was posted to NASA's Jet Propulsion Laboratory for the MARS-Jupiter-Saturn (MJS-77), which later became the Voyager mission, which is still operating and returning data from outside the solar system at this writing.

The author has been at almost all of the facilities and launch sites discussed, in an official capacity. There is always time to slip away and visit the museums.

Mr. Stakem is affiliated with the Whiting School of Engineering of the Johns Hopkins University. He received NASA's Space Shuttle Program Managers commendation award, as well as two NASA Group Achievement awards, the NASA Apollo-Soyuz Test Program Award, and a Certificate of Appreciation, NASA Earth Science Technology Office. Mr. Stakem has completed over 42 NASA Certification Courses in various areas

## **What is NASA?**

The National Aeronautics and Space Administration supports aerodynamic and space flight for non-military purposes. In their own words, NASA's Vision is 'We reach for new heights and reveal the unknown for the benefit of humankind.' That's what they have been doing for nearly 60 years now, since President Eisenhower established the agency in 1958. It was an expansion of the National Advisory Committee on Aeronautics (NACA), which at the time was 40 years old. NASA is still involved in winged flight, but is best known for its work in Space. Even as I type, Astronauts aboard the International Space Station are working to improve our life on Earth, and our understanding of our place in the Solar System and the Galaxy. NASA manned missions have been to the Moon, and robot spacecraft have visited all the planets of our solar system. There's a lot more work to do.

NASA has a tremendous outreach program, and a lot of online material. Get the *ISS Live* app from your Android Phone – it lets you see in real time where the ISS is, and shows you the view from one of its cameras (when in sunlight only).

## **NASA's History**

NASA was formed to respond to the Soviet Union's launch of the first artificial satellite of the Earth. President Kennedy focused America's efforts on a race to the Moon, then seen as the goal for Mankind. The Space Race was off and running, with seemingly unlimited resources devoted to that goal. Kennedy stated the national goal of landing on the moon in the 1960's. This goal was achieved, but unfortunately Kennedy was not alive to see it. NASA partners with the National Oceanographic and Atmospheric Administration for weather, climate, and disaster monitoring from space. It is also the focal point for exploration of the rest of the Universe, the other planets in our solar system, stars, galaxy's and whatever is out there. NASA co-operates with other space-faring nations on joint projects.

NASA continued its leadership in aeronautics, and built the infrastructure we have come to rely on, the weather satellites, and the communication relay satellites, (a concept of Science Fiction Writer, Sir Arthur C. Clarke,) and the Global Positioning System (GPS), so we don't need hard-to-fold paper maps any more.

## **NASA organization and structure**

NASA consists of a Headquarters organization in Washington, D. C., ten Field Centers across the Country, specializing in different aspects of atmospheric and space flight, two assembly facilities, and two launch sites.

As government facilities, the NASA centers will be closed on Federal holidays, but privately operated visitors centers are

generally open. Check days and hours online. ([www.visitnasa.com](http://www.visitnasa.com)). In addition, these are all Federal facilities, with tight security. Generally only employees are allowed on the facility, and the visitor center is separate, outside the secure area. NASA has passed the management of some of its Visitor Centers to private enterprise, such as at Johnson Space Center in Houston, Texas, and Kennedy Space Center in Florida. The privatized visitor centers, really museums, charge admission to help preserve the artifacts. Check into the NASA Passport program via the website for special offers, and a passport to get stamped as you visit the various centers.

(<http://www.visitnasa.com/nasa-passport-to-explore-space>)

Here is a quick list of the NASA Centers, and related Visitor Centers.

Ames Research Center, Moffitt Field, California – government operated. Facility tour with advanced reservations.

Armstrong Flight Research Center, Edwards Air Force Base, California – government, U. S. Air Force, with increased security. Pre-arranged tours.

Glenn Research Center, Cleveland, OH – private, downtown Cleveland, admission fee.

Goddard Space flight Center, Greenbelt, MD – privately operated, free.

Jet Propulsion Laboratory, Pasadena, California – Government operated; tours with some restrictions.

Johnson Space Center, Houston, TX – Privately operated, admission fee.

Kennedy Space Center, Florida - Privately operated, admission fee.

Langley Research Center, Hampton, VA – private, admission charged.

Marshall Space Flight Center, Huntsville, AL - Privately operated, admission fee.

Michoud Assembly Facility, New Orleans – no visitor's center

Stennis Space Center, Louisiana – private, museum and bus tour.

Wallops Flight Center, Virginia – Government operated, pre-scheduled tours.

Headquarters and the Field Centers are listed in alphabetical order. The details are presented below.

## **Ames**

NASA's Ames Research Center is in Mountain View, California, in

Silicon Valley. It is on the site of Moffett Field, a former Naval facility. NASA has several of its planes at the facility, and there are very large wind tunnels and hangers. Google is also a tenant at the site,

The visitor's center is free, hosted in a large inflatable building. They are open every day except Monday, and federal holidays. They have a moon rock, and a Mercury-Redstone rocket and capsule from the last unmanned flight.

### ***Armstrong Flight Research Center***

The Armstrong Center is the renamed Dryden Facility in California, and focuses on Atmospheric flight. It is now part of Edwards Air Force Base. This was the main site for the X-15 flights, and the Shuttle test landings.

from their website:

“Since NASA Armstrong Flight Research Center is located on Edwards Air Force Base, only military, those who can access the base as credentialed civil service and government contractors, or those who have visitor permits will be admitted. There is a NASA gift shop and Visitors' Center that you can visit if you are on the base.”

Unfortunately Armstrong tours were canceled a few years ago due to budget cuts.

Public tours of Edwards Air Force Base are still being offered by the Air Force Test Center's public affairs office. The Edwards tours include a visit to the Air Force Test Center museum as well as a bus tour of the main base area.

For more information about the Edwards Air Force Base public tours, visit [www.edwards.af.mil](http://www.edwards.af.mil) and click on the "Tours" link on the menu bar at the top of the home page. A schedule of planned public tours is listed, along with information on how to make

reservations to participate in a tour. For further information, call the Edwards Air Force Base public affairs civic outreach office at 661-277-3517 or 661-277-4803.”

## ***Glenn***

The Glenn Research Center is at Lewis Field in Cleveland, Ohio. The Visitor's Center was moved to the Great Lakes Science Center in downtown Cleveland. Admission is free. The Glenn facility offers tours on the first Saturday of every month. Glenn works on projects in spacecraft propulsion, and Zero-gravity effects. Established in 1942, it used to be involved in aircraft engine research. It was previous named the Lewis Research Center, after a former director of NACA. Glenn has the responsibility for the Crew Exploration Vehicle's service module, a key part of the new Orion project.

## ***Goddard***

The Goddard Space Flight Center is the hub of the NASA world wide communications Network, and the Lead Center for unmanned spaceflight. It was dedicated in 1959 by rocket pioneer Dr. Robert Goddard's widow. Goddard is the lead NASA center for unmanned spacecraft. It has worked on hundreds of spacecraft projects, including the Hubble Space Telescope, and the upcoming James Web Space Telescope.

The NASA Visitors Center is located off of IceSat Road, which is a turn off of Greenbelt Road. The Main Gate (employees only) is at 8800 Greenbelt Road, and Icesat Road is East of the Main gate. After turning on Icesat Road, make the next left turn into the Visitor's Center parking lot. Admittance is free. There is a gift shop and bathrooms. Down the hill is Bldg. 14, NASA's communications nerve center, NASCOM. A must see is the awesome *Science on a Sphere* presentation, which takes about 45 minutes.

Outside on display— All of these rockets are flight hardware. Delta-B (Thor-Delta) rocket, various sounding rockets, Apollo

boilerplate Capsule. Inside, they used to have a Gemini capsule, but it got sent to Ohio. They have a International Space Station model, Hubble Space Telescope Model, Lunar Reconnaissance Orbiter full-size Engineering model, and James Webb Space Telescope model.

Sounding Rockets on display include a Black Brant VIII, Argo D-4 Javelin, Nike-Tomahawk, and IRIS. Just outside the back door of the building, in the area where the rockets are, note what looks to be a tent on tracks. Those are solar arrays, and that is Grover, the Greenland Rover. It includes the drive motors, but the electronics were removed. It is the engineering model of a multi-year project I participated in, where student from all over the western Hemisphere (University of Alaska, Anchorage to Terra del Fuego) assembled, tested, and deployed the unit to Greenland. I carried an ice-penetrating radar to measure the depth of the ice shelf, and to determine trends – was it receding, and how quickly. The unit used a satellite link for communications, and stored its science data onboard. It was, in a sense, a satellite at zero altitude.

## ***Headquarters***

NASA Headquarters is located at 300 E street SW in downtown Washington, D. C. It provides oversight, guidance, and direction to the field centers, and is the liaison of the Agency with Congress.

NASA is organized in four Mission Directorates, Aeronautics, Human Exploration and Operations, Science, and Space Technology.

NASA HQ has no Visitor Center, and access cannot be gained without sponsorship of a NASA employee. However, just across the street is the Smithsonian's Air and Space Museum, a must-see, and it's free.

There is a second Smithsonian Air and Space Facility, The Udvar-Hazy Center, located near Dulles Airport in Virginia. There is a Shuttle bus between the two facilities. Parking at the Dulles facility is not free, but admission is.

Mercury capsule-6, *Friendship 7*, flown by John Glenn, and MA-15B, not flown, originally scheduled for Alan Shepard, is at the Smithsonian Dulles facility. The Gemini capsule flown by McDivitt and White, number 4, is at the DC museum. Number 7, flown by Borman and Lovell, is at the Dulles facility, as are the units involved in the Gemini Para-glider program, the TTV-1, or towed test vehicle. The Apollo-11 command model, *Columbia*, is in Washington, as is the Command Module that flew Crew 3 to the Skylab. An unflown Skylab is also at the Museum. The Shuttle *Discovery* is at the Dulles facility. They also have a SpaceLab that flew in the Shuttle 9 times.

Another item of interest at the Air & Space in D. C. is an Apollo-Soyuz and a German V-2 rocket.

## ***Houston***

The Johnson Space Center in Houston is the lead center for Manned spaceflight. Control and authority over the mission transition from KSC to JSC Mission Control when the vehicle clears the launch tower, which took about 12 seconds after first stage ignition, for Apollo.

The Mission Control Center (MCC) was used for the Apollo and Shuttle flights, and is still used for Space Station operations. It has been renamed the Christopher C. Kraft (the “Voice of Mission Control”) Mission Control Center. It consists of one large operational control center that operates 24x7, with resources for the various flight controllers. Because of the possibility of hurricanes in the Houston-Gulf area, there are backup sites at MSFC in Huntsville, and GSFC in Maryland. The original Control Center developed for the Apollo Lunar landings was driven by a large IBM Mainframe Computer (System S/360). A similar configuration was used at Goddard and Marshall. These facilities were up and operational during any Mission, and could take over control quickly. NASCOM, the NASA worldwide communication network was located at Goddard Space Flight Center, and connected to the world-side network of tracking stations, tracking

ships, and aircraft. All the data flowed into the basement of Building 14 at Goddard, and was distributed to the various NASA Centers as required. A direct line from the launch site in Florida to the Marshall Space Flight Center in Alabama was maintained.

A Univac 481 mainframe computer from MCC at Houston, is at the American Computer & Robotics Museum in Bozeman, Montana, if you're in the neighborhood.

Space Center Houston is the privately operated visitor center adjacent to NASA's Johnson Space Center. << [www.spacecenter.org](http://www.spacecenter.org) >>. There is an admission fee. It is an affiliate of the Smithsonian. JSC also has a Little Joe Rocket, which was used to test the Mercury capsules.

The Center has a Saturn-V moon rocket and a Shuttle Mock-up atop one of the two original Shuttle Carrier Aircraft (747).

## **JPL**

The Jet Propulsion Laboratory in Pasadena, California, is operated for NASA by the California Institute of Technology. JPL has responsibility for payloads going to planets other than Earth. It also operates the Deep Space Network, which communicates with spacecraft going to, or operating on the surface of other planets. Part of the facility is designated as a National Historic Landmark.

The lab was started in 1936 as the Guggenheim Aeronautical Lab, and was active in early rocket work. It developed the JATO (jet assisted take off) unit for heavily loaded bombers in World War-II. It went on to develop some of the early ballistic missiles for the Army. It became a NASA facility in 1958.

JPL has a "Ticket to Explore" program, which requires advanced reservations. The tours generally run on Monday or Wednesday at 1:00 pm, and lasts about 2 hours and are free. Check their website

JPL also runs NASA's Museum Alliance, that brings programs,

exhibits, and expertise to museums and education institutions. There are 700 participating organizations around the world. See <https://www.jpl.nasa.gov/edu/news/2016/2/25/whats-the-museum-alliance/>

## **Kennedy Space Center**

Kennedy Space Center occupies a portion of the Cape Canaveral Air Force Station on Florida's south east coast.

The Saturn moon rockets were assembled at the Cape vertically in the Vehicle Assembly Building at (VAB), on the Crawler-transporter, and checked out for flight. Before being erected on the crawler, each stage was inspected and tested after delivery. The stages had been checked out individually before shipment to the launch site. In the first three Saturn V flights, 40 serious defects were found and corrected at this point.

Launch Complex 39 at KSC was used to launch the Lunar Missions. It has two launch pads, 39a and 39b, and included the Vertical Assembly Building and the connecting crawler way. These were later used for the Space Shuttle Program.. The crawler was built by the Marion Power Shovel Company, of Marion, Ohio.

When the various stages of the Saturn-V vehicle were assembled in the VAB, the Apollo “stack” was connected to the Launch Control Center for checkout, via a high speed data line. After checkout, the crawler-transporter picked up the vehicle and its support base, and moved it to the launchpad. Here, the vehicle was connected to data lines leading from the pad to the LCC again.

The Launch Control Center at Kennedy Space Center had control of the Apollo launch until the vehicle cleared the launch tower, at which point control transferred to Mission Control in Houston. The LCC is Building 30 at KSC, located near the Vertical Assembly Building. It has two facilities called the Mission Operations Control Rooms. One is on the second floor, and the other is on the third floor. The lower floor was filled with mainframe computers

and communications equipment. Room number 2, used for the Apollo Missions, including the Lunar Landings, was designated a National Historic Landmark and has been restored back to its original configuration.

Both in the VAB and at the pad, RCA computers in the LCC controlled the automated testing and verification. Tests are conducted from one of the two firing rooms in the LCC.

For checkout operations, a firing room would be occupied by up to 400 engineers, with additional support personnel in a backup room. There were 400 consoles, 100 of which were CRT displays. There was also four large overhead screens with projectors.

The Kennedy facility has one of the iconic Saturn-V rockets. It also hosts a Mercury capsule, used in early unmanned tests.

Be sure to see the Astronaut Hall of Fame, and the Fallen Astronauts memorial. There is a former classmate of mine whose name is on the memorial. Space flight is neither easy, or safe.

There is an Orion manned capsule mock-up. This is the new 4-person capsule for manned lunar and Martian explorations. The Kennedy facility has the Gemini 9 capsule flown by Stafford and Cernan. It also has the Apollo 14 Command Module, *Kitty Hawk*, and the Shuttle *Atlantis*. There is also a Soviet-era Soyuz manned spacecraft.

One of the least known tours is the Cape Canaveral Early Space Tours. These are conducted Thursday through Sunday, with registration between 9-11 on the day of the tour. U.S. Citizens need a government-issued ID such as a driver's license, passport, or military ID. Foreign Visitors need a valid passport.

## ***Langley***

The Langley Research Center is in Hampton, Virginia. It is NASA's oldest center, and the lead center for aeronautics. It was

established in 1917 by NACA, the fore-runner of NASA. It hosts the NASA Engineering and Safety Center, and the Virginia Air and Space Center. It initially hosted the NASA Task Group, established for research into manned space flight, which was later moved to Houston. Langley did support the lunar missions with the Lunar Landing Research Facility.

The Virginia Air and Space Center is the visitor's center at Langley. There is a fee. From here, visitors may talk to the crew of the International Space Station, among other things. The Mercury-14 capsule, flown in an unmanned test, is at the center, as is the Apollo-12 Command Module, *Yankee Clipper*. It also has a Lunar Excursion Module Simulator, and a full scale mockup of the Viking lander for Mars. It has a hatch from Gemini 10 and the Mercury XIV. It also has some moon rocks.

## ***Marshall***

The George C. Marshall Space Flight Center, located in Huntsville, Alabama, is the lead center for spacecraft propulsion research. It's on the grounds of the U. S. Army Redstone Arsenal, which is where the von Braun German rocket team was brought after World War-II. Marshall as a center pre-dated NASA itself.

The initial work was getting the captured V-2's to fly at White Sands, New Mexico. The V-2 was made into a two stage vehicle with the addition of an Army WAC Corporal missile. Project Bumper, as it was called set an altitude record of 250 miles. The Team went on to develop much improved V-2's, called the Redstone and the Jupiter. A Redstone carried Alan Shepard, the first American into space.

Later, Marshall was the lead center for development of the Saturn Moon Rocket. Project Horizon was to have used the Saturn to establish an Army outpost on the Moon. In 1959, all Army space-related activities were transferred to NASA. Besides the Saturn vehicles, MSFC had responsibility for the Space Shuttle main

engines. Space Camp is held at Marshall, with the program open to kids from the U.S. or foreign countries. It goes from Grade 4 to adult, and there is a few for the program, which lasts several days.

Marshall hosts the Alabama Space and Rocket Center Museum. It has, among other exhibits, a Saturn-V moon rocket and an entire Shuttle stack, with external tanks and solid rocket boosters. It hosts the Apollo-16 Command Module *Casper*; an X-15, and a Lunar Lander (LEM) mockup. The complete Saturn-V rocket is a designated National Historic Landmark. Their Rocket Park has 27 rockets on display.

## ***Michoud Assembly Facility***

The Michoud facility is administratively a part of the Marshall Space Flight Center, and was built to support construction and integration of the massive Saturn-V moon rockets. These were so large they were delivered by barge to the Kennedy Space Center. For the Space Shuttle Program, Michoud was used to assemble the large external fuel tank. It is located east of New Orleans, Louisiana. It was established in 1961, and was originally a land grant to a local merchant from the King of France. It is named after Antoine Michoud, a Napoleon-era administrator in the area. The site was used as a sugar cane processing plant. Later, the site was used as a shipyard to construct Liberty Ships and Cargo aircraft during World War-II. During Hurricane Katrina, 37 employee's stay on site to monitor and protect the facility. These were awarded the NASA Exceptional Bravery Medal.

Covering more than 830 acres, it has one of the world's largest production buildings, the vertical assembly building, to support the assembly of the Shuttle external fuel tank. A total of 136 of these tanks were constructed and delivered to Kennedy Space Center, and 135 flew. The facility is being modified to support the 2018 launch of the NASA's new Space Launch System.

Michoud does not have a Visitor's Center, and entry requires sponsorship of a NASA Employee.

## ***Stennis Space Center***

The John C. Stennis Space Center was named for a U. S. Senator from Mississippi who served for 41 years. It is NASA's major rocket testing facility. It was originally called the Mississippi Test Facility, and was located between the Michoud Manufacturing Facility in New Orleans, and the Kennedy Launch Facility. Since the rocket motors for Apollo were too large for overland or air transport, it was located near water, for barge usage. The facility was constructed by the U. S. Army Corps of Engineers on sparsely populated land. Even so, some 700 families had to be relocated, including their schools and churches. The site covers 15,000 acres. It contains a large number of rocket test stands. The facility is still in use by NASA, and various private launch vehicle companies,

The associated Infinity Science Center has a walk-through Space Station mock-up. It also has the Apollo 4 Capsule, and a cut-away Orion capsule. There is an admission charge.

## ***Wallops Flight Facility/MidAtlantic Regional Spaceport***

The Wallops Flight Facility (WFF), renamed the Mid Atlantic Regional Spaceport, is located at Chincoteague, Virginia on the Atlantic Ocean. It supports sub-orbital and orbital flights. It is administratively under the Goddard Space Flight Center. It has a small museum and gift shop. It is possible to see a launch from Wallops – check their website for times. However, be aware, not everything goes smoothly at a launch, and the launch might be slipped hours, days, or be rescheduled. The little town of Assateague is near-by with motels and restaurants, and a nice beach. The State park, to the south is worth a visit, and is the where the ponies who live on the wildlife refuge on Chincoteague Island swim over to the mainland now and then.

Mosquitoes are numerous in the warmer months. We used to say that they could get landing clearance to use the runway. Take Mosquito repellent, and sun screen. Wallops launches sub-orbital

payloads, sounding rockets, and Space Station resupply missions.

The Visitor's Center, Building J-20T, is located on Route 175, six miles east of US-13 and five miles west of Chincoteague Island, VA. It is free.

<https://www.nasa.gov/centers/wallops/visitorcenter>

Also get the NASA WFF ap. This keeps you up to date on what's happening, and when the next launch is scheduled.

### ***International Space Station***

Another NASA facility you might like to visit is the International Space Station. It's possible, but extremely expensive. Great views. Limited sleeping arrangements and toilet facilities. It has been visited by "space tourists" from 17 nations.

However, the NASA ISS ap for cell phones is great. It shows the point on the Earth the Station is above at the time, and has a high resolution camera that returns images (during Sun-lit portions of the orbit). The ISS can be seen from the ground, when the angles and lighting are right – there's an ap for that.

On-orbit construction of the ISS began in 1998. The heavy lifting was done by Russian Proton and Soyuz launch vehicles, with the Space Shuttles acting as habitats as the construction was in progress. Now, it is truly an ongoing international project.

The facility has been continuously occupied since November of 2000. It sees regular re-supply missions, usually unmanned, that brings up new consumable. The "trash" is loaded into these units, and it burns up in the atmosphere upon re-entry. Personnel change-out is done with a Soyuz MS-02 vehicle. Material can be returned to Earth on the Space-X Dragon spacecraft.

The ISS is controlled from the Marshall Flight Center in Huntsville, AL, and the Johnson Space Center in Houston. The

European Space Agency controls their Columbus module from a center near Munich, Germany.

## Where to See ...

This section will discuss where to see specific historic spacecraft and artifacts.

### ***Saturn-I vehicles***

The Saturn 1 was the first in a series of heavy lift rockets, leading to the Saturn-V. It could lift 9,000 kg to low Earth orbit (LEO) from launch complex LC-37 at the Kennedy Space Center in Florida. It was 180 feet long and 21.4 feet in diameter. The first flight was in October of 1961. The second stage, the S-IV, had six RL-10 engines, burning liquid hydrogen and liquid oxygen. A burn time of around 480 seconds could be achieved. Block-II vehicles were used in flights 6 through 10.

With the Instrument Unit, Apollo payload, and Launch Escape System (LES), the total vehicle configuration stood 57.3 meters tall, with a weight in excess of 513,000 kg. An Instrumentation Unit is at the Smithsonian's Udvar-Hazy Center. The IU is the guidance computer for the Saturn vehicle.

All ten launches of the Saturn-I models from 1961 to 1965 were successful. The follow-on to the Saturn-I was the Saturn-IB, and the follow-on to that was the larger Saturn-V vehicle, required to achieve a trans-lunar trajectory. The Saturn IB had 9 successful launches, including the post-Apollo Skylab and Apollo-Soyuz missions. Saturn-V rockets were used for the 13 lunar mission launches. There were no failures of the Saturn launch vehicles in any of their flights, a tribute to the engineering prowess and attention to detail of the von Braun team.

A Saturn-I vehicle can be seen at Huntsville, and a 1B model is at Kennedy Space Center in Florida..

## **Saturn-V Moon Rockets**

The Saturn vehicles were developed by the von Braun team at Marshall Space Flight Center, formally the Army's Redstone Arsenal, in Huntsville, Alabama. Von Braun and his team of scientists and engineers had been brought to the U.S. by the Army after World War II ended. The rocket program was kicked off during the early post-World War-II Cold War era by President Eisenhower. At the time, the United States was in a race to space, and particularly, a launch vehicle race, with the Soviet Union. Each U. S. military service, the Army, Navy, and Air Force were developing their own rockets. Inter-service rivalry was finally squashed by Secretary of Defense Charles Wilson, who decided in November of 1956 to make the Air Force the primary missile developer for long range ballistic and space missions. The specifications for a heavy-lift vehicle were developed by the Advanced Research Projects Agency (ARPA). This would eventually become NASA's Saturn-V.

The Apollo payload consisted of the Launch Escape System, the Apollo capsule, the service module, and the lunar lander. The launch escape system (LES) was located above the Apollo capsule and was jettisoned early in flight. The Lunar Excursion Module (LEM) was stored behind the service module. Once in Earth orbit, the capsule and Service Module were separated, the capsule rotated 180 degrees, and docked to the Lunar module. The lunar package was then separated from the third stage. The capsule, lander, and service module left Earth orbit heading for the moon, while the Third stage was commanded into a solar orbit, to get it out of the way.

The Command Module, or Apollo capsule, was the cockpit and living quarters for the three astronauts. The computing heart of the capsule was the unique Apollo Guidance Computer. The need for a computer onboard the Apollo was required by the chosen approach to the mission. Part of the spacecraft (Command and Service Modules) would remain in lunar orbit, while a detachable part (LEM) would descend to the surface. Later, the LEM would return

to lunar orbit and rendezvous with the Command Module, which would then leave lunar orbit and return to Earth. The ability of the Command Module and LEM to do in-flight computations was crucial to this approach. At the time, the only guidance computes were developed for ballistic missiles, and were buried in hardened bunkers.

The Service Module was located behind the Command Module, and the astronauts had no direct access to it. It was unpressurized, and contained a restartable liquid rocket engine and associated propellant, fuel cells, and electronics to support the mission. The fuel cells used hydrogen and oxygen, and some oxygen was also used to replenish the Command Module atmosphere. It had a reaction control system to adjust the spacecraft attitude. The service module had radiators to dump excess heat, and a high gain antenna to communicate with Earth. The Command Module stayed attached to the Service Module until just before reentry into the atmosphere, when the Service module was commanded to reenter the atmosphere independently and burn. The Service Module relied on the AGC in the Command Module for computation.

The lunar excursion module allowed a two man crew to land on the lunar surface, stay for a period of exploration, and return to the Apollo Command and Service Modules in lunar orbit. It had an Apollo Guidance Computer, programmed for the different and difficult tasks of landing on the lunar surface, and later taking off from the surface. Compared to the Launch complex at KSC with all its support infrastructure, the computer in the LEM did not have a lot to work with.

The LEM had two sections, one of which held the descent engine, and stayed behind on the Lunar Surface. The Ascent Stage, holding the two astronauts, rendezvoused with the Command and Service module in lunar orbit. The LEM was deliberately deorbited and crashed into the lunar surface, to facilitate seismometer readings for the lunar geologists..

At Earth launch, the Lunar Module was located between the third

stage of the Saturn-V vehicle, and the command module, in the Lunar Module adapter. The command module/capsule was detached, and turned around to dock with the lunar module. When that was latched in place, the assembly was turned back to an intercept orbit to the moon, and the command module's main engine was fired. It would fire again to achieve a lunar orbit, to depart the lunar orbit after the surface exploration, and to enable reaching Earth orbit.

The first stage of the Saturn Rocket "stack" was the heavy lift stage, consisting of five Rocketdyne F-1 engines, one fixed in the middle, and four outside units that could swivel for steering and attitude adjustment. The first stage booster did not incorporate active guidance. The stage's job was to get the rocket and its payload from a standing start to 67 kilometers up, 93 kilometers downrange, and moving at 2,300 meters per second. That required 168 seconds of engine burn time. The total thrust developed by the engines was 7,600,000 pounds-force. Most of the first stage was fuel. The dry weight was about 130 tons, and the fueled weight was 2,300 tons. Any deviation of the vehicle during first stage burn was noted, and adjusted for during the second stage burn.

The engine's sequence of events was controlled by an onboard sequencer. This was not a computer, but just a fixed series of commands that were played out in time sequence. The center engine of the stage was started 8.9 seconds before launch, with pairs of outboard engines starting at 300 millisecond intervals. This technique was used to reduce structural loading on the rocket. When the computer in the Instrument Unit confirmed thrust level correctness, the pad hold-down arms released the rocket. In the Instrument Unit, the Saturn Emergency Detection System (EDS) inhibited engine shutdown for 30 seconds after launch. It was calculated that this was safer than having a shutdown early in the sequence, which would result in a non-survivable event for the astronauts.

The sequencing of events took place on a prearranged timeline. As

the vehicle lifted past the tower, it was yawed 1.25 degrees away from the tower, to provide a margin of safety in high winds. Past 400 feet, a pitch program kicked in, having been adjusted for the expected winds that month. The vehicle also rolled to the correct flight azimuth. The outboard engines were tilted to the outside, so their thrust vectors went through the vehicles center of gravity. This was to minimize the effect of one outboard engine failing. At roughly 1 minute into the flight, the vehicle broke the sound barrier. Guidance adjustment was provided by the computer in the Instrument Unit (IU). The initial trajectory was designed to gain altitude quickly as the main goal. The engines; thrust grew from 7.5 million pounds-force at launch to over 9 million, in the thinner air. At the same time, the mass of the vehicle went down dramatically, as fuel and oxidizer was burned at the rate of 13 tons per second. The maximum acceleration was reached in over two minutes, at 4 G's. At this point, the center engine was shut down to limit acceleration, and the four outer engines used the remaining fuel and oxidizer. When oxidizer or fuel depletion was sensed at the pumps, the first stage was separated from the vehicle. Up high and moving fast, the first stage was separated, splashed down in the Atlantic, and the rest of the vehicle headed for Earth orbit.

Saturn-V displays are located at Kennedy, Houston, and Marshall (U. S. Space & Rocket Center).

In addition, Saturn-V first stage engines (F-1) can be seen at the Smithsonian National Air and Space Museum, Washington, DC; Kalamazoo Aviation History Museum (Air Zoo), Kalamazoo, MI; New Mexico Museum of Space History, Alamogordo, NM; and Powerhouse Museum, Sydney, Australia.

## ***Mercury Capsules***

The Mercury capsule carried a single person, with a limited duration on orbit. Several suborbital flights were made with chimpanzees and, later, Astronauts, before the first orbital flight. Mission duration was 3 orbits, about 4 1/2 hours.

Alan Shepard was the first to ride in one, a suborbital flight in May of 1961. The sub-orbital flights used the Redstone launch vehicle, but an Atlas rocket was used to achieve orbit. John Glenn, the first American to orbit the Earth, rode one in 1962.

There is a Mercury capsule used in unmanned test at Kennedy Space Center, Cape Canaveral, FL. The Mercury 14 capsule is at the Virginia Air and Space Center, Hampton, Va. John Glenn's MA-6 "Friendship 7" is at the National Air and Space Museum in Washington, D.C.

Wally Schirra's MA-8 "Sigma 7" is at the Astronaut Hall of Fame, Titusville, FL. Gordon Cooper's MA-9 "Faith 7" is at the Space Center Houston.

Capsule #10 (unflown) can be found at the Kansas Cosmosphere and Space Center, Hutchinson, KS. Mercury 12B (unflown) is in storage at the National Air and Space Museum, Garber Facility, Suitland, MD. Mercury 19 (unflown) is at the McDonnell Planetarium, Saint Louis, MO. MA-15B (unflown). can be seen at the National Air and Space Museum, Steven F. Udvar-Hazy Center, Chantilly, VA. Mercury 17 (unflown) is at the U.S. Air Force Museum, Wright-Patterson Air Force Base, Dayton, OH.

## **Gemini Capsules**

The Gemini was a two-person capsule, launched to orbit on an Titan-II vehicle from launch complex 19 at Cape Canaveral Air Station, FL (Now, Kennedy Space Center). It was a follow-on to the earlier Mercury Project, and proved designs and concepts for the following Apollo Project. The program ran from 1961 to 1966, with test flights in 1965 and 66. Gemini proved, in orbit, missions as long in duration as would be necessary for the lunar flights were feasible. Also, Gemini proved extra-vehicular activity, with space suited astronauts outside the capsule, worked fine. Gemini also helped validate the procedures for rendezvous and docking of two spacecraft, essential for Apollo. The Gemini missions used the Titan ICBM, updated to be man-rated. Here were two unmanned

flights in 1964-1965 to test the reentry heat shield.

The Air Force eyed using the Gemini capsule for their own Manned Orbiting Lab (MOL) Program, but that program was canceled before any flights were made.

The Gemini-TTV (towed test vehicle) used a large paraglider and deployable wheels to enable the capsule to land at an airfield. Testing was done at Edwards Air Force Base in California. This program was canceled in 1964. After de-orbit, the regular Gemini capsules landed in the ocean, as had Mercury.

Number 1, unmanned, was intentionally burned in the atmosphere, but number 2 was recovered and is at the Air Force Space & Missile Museum, Cape Canaveral Air Force Station, Florida. Number 3 "Molly Brown" (Grissom, Young) is at the Grissom Memorial Museum, Mitchell, IN. Number 4 (McDivitt, White) is at the National Air and Space Museum (Smithsonian Institution), Washington, DC. Number 5 (Cooper, Conrad) is at Space Center Houston. Number 6-A (Schirra, Stafford) is at the Oklahoma History Center, Oklahoma City, OK. Number 7 (Borman, Lovel) is at the National Air and Space Museum, Steven F. Udvar-Hazy Center, Chantilly, VA (Dulles Airport).

Number 8 (Armstrong, Scott) can be seen at the Neil Armstrong Museum, Wapakoneta, OH. Number 9 A (Stafford, Cernan) is at the Kennedy Space Center, Cape Canaveral, FL Number 10 (Young, Collins) is at the Norwegian Technical Museum, Oslo, Norway. (one of the hatches is on display at the Virginia Air and Space Center, Hampton, VA). Number 11 (Conrad, Gordon) is at the California Science Center, Los Angeles, CA. Number 12 (Lovell, Aldrin) is at the Adler Planetarium, Chicago, IL Capsule SC-2A (unflown backup) is at the Kansas Cosmosphere and Space Center, Hutchinson, KS (original shell with a restored interior).

TTV-1 "El Kabong 1" unmanned towed-test vehicle, used in the Gemini Paraglider Program is at the National Air and Space Museum, Steven F. Udvar-Hazy Center, (Dulles Airport) Chantilly,

VA.TTV-2 is at the Museum of Science & Industry, Manchester, England, U.K.

An unflown mockup, used for training, can be seen at the Michigan Space Center, Jackson, MI, the Museum of Science and Industry, Chicago, IL, and the Louisville Science Center, Louisville, KY. An engineering mockup decorates the James S. McDonnell Prologue Room, Boeing Corporation, Saint Louis, MO. A full-scale model is at the Oregon Museum of Science and Industry, Portland, OR, and an unflown mockup can be seen at the Pacific Science Center, Seattle, WA. An unflown mockup, with landing gear, is at the National Museum of Scotland, Edinburgh, Scotland, U.K.

## ***Apollo Capsules***

The Apollo spacecraft were the payloads on the Saturn Ib and V vehicles. These include the Command Module that held the 3 astronauts, the Service module that contained equipment, and the lunar module. The Lunar lander bases were left on the lunar surface. After the crew returned to the Command Module, the ascent stage of the lander was crashed into the lunar surface, to provide controlled moon-quakes for seismometers on the surface. The Service Modules were jettisoned before reentry into Earth's atmosphere, reentered, and burned.

Apollo-1 is the Command Module that suffered a disastrous fire during test with the crew trapped inside. At one point there were plans to store the Apollo 1 CM in the same silo as the Shuttle Challenger debris, but it was later decided that Apollo-1 would remain at NASA Langley Research Center. It is not on display to the public.

There was no Apollo-2 or -3. This was due to a renumbering of missions and equipment, following the Apollo-1 fire. The widows of the Apollo-1 Crew requested NASA to retire the mission number.

Apollo-4's Command Module is at NASA's John C. Stennis Space Center in Bay St. Louis, Mississippi.

Apollo-5 was an unmanned Earth orbital test, and both the Capsule and Lunar modules reentered the atmosphere and burned, after successful on-orbit testing. Apollo-6's Command Module is at the Fernbank Science Center, in Atlanta, Georgia. Apollo-7's Command Module is at the Frontiers of Flight Museum, Dallas, Texas. Apollo-8's Command Module is at the Chicago Museum of Science and Industry, Chicago, Illinois.

Apollo-9's Command Module "Gumdrop" is at the San Diego Air and Space Museum, San Diego, California. Apollo-10's Command Module "Charlie Brown" is at the Science Museum, Kensington, London. The Lunar Module "Snoopy" is in orbit about the Sun.

Apollo-11's Command Module "Columbia" is at The National Air and Space Museum, Washington, D.C. The Lunar Module "Eagle" was jettisoned from the Command Module on 21 July 1969 at 23:41 UT and its impact site on the moon is currently unknown. Perhaps the Lunar Reconnaissance Orbiter can find it. Apollo-12's Command Module "Yankee Clipper" is at the Virginia Air and Space Center, Hampton, Virginia. The Lunar Module "Intrepid" impacted the lunar surface on 20 November 1969.

Apollo-13's Command Module "Odyssey" is at the Kansas Cosmosphere and Space Center, in Hutchinson, Kansas. The Lunar Module "Aquarius" burned up in Earth's atmosphere in April, 1970. It was the lifeboat for the astronauts, after the Service Module exploded on the way to the Moon. It was jettisoned before the manned capsule reentered the atmosphere.

Apollo-14's Command Module "Kitty Hawk" is at the Visitor's Center, Kennedy Space Center, Florida. The Lunar Module "Antares" impacted the lunar surface. Apollo-15's Command Module "Endeavor" is at the USAF Museum, Wright-Patterson Air Force Base, Dayton, Ohio. The Lunar Module "Falcon" impacted

the lunar surface.

Apollo-16's Command Module "Casper" is at the U.S. Space and Rocket Center, Huntsville, Alabama. The Lunar Module "Orion" was jettisoned April 24, 1972, and impacted the lunar surface at an unknown location.

Apollo-17's Command Module "America" is on view at the NASA Johnson Space Center, Houston, Texas. The Lunar Module "Challenger" was jettisoned and impacted the lunar surface. An Apollo unflown Test article is at the Visitor's Center, NASA/GSFC, Greenbelt, MD.

Apollo 18, 19, and 20 were canceled, and some of the hardware was used for the Skylab project.

## **Apollo-Soyuz**

The Apollo-Soyuz Test Project was a joint space project between the Soviet Union and the United States to fly a simultaneous missions that would meet up and join on-orbit. It was conducted in July, 1975. The author supported the Apollo-Soyuz mission. The Apollo Command Module is at the California Science Center, Los Angeles, California. You can see a coupled Apollo-Soyuz at the Smithsonian Air & Space Museum in D. C. The Apollo is the unit used for pre-flight testing, and the docking module between the craft is the back-up model, made by North American Rockwell. A similar display is at the Cosmosphere, in Hutchinson, Kansas. The actual Apollo capsule from the flight is on display at the California Science Center in Los Angeles. If you want to see Soyuz-19 that made the flight, you will have to go to the RKK Energiya museum in Korolyov, Moscow Oblast, Russia.

The Apollo was the last of its kind to fly, as it was replaced by the STS- Space Shuttle for further manned missions. Despite the technical and ideological differences, the mission was a great success, with real science being conducted.

At the time of the joint flight, tensions between the then-Soviet Union and the United States ran high. This successful project was proof of “detente” and cooperation.

## ***Skylab***

America's first space station used surplus Apollo hardware. This involved an emptied Saturn IVB stage as the structure for the station, filled with science instruments and living space, and launched by a Saturn-V with live first and second stages. Astronauts were carried to the facility in-orbit on three missions in 1973-1974 by Apollo capsules on Saturn-Ib vehicles.

The first Skylab mission lasted 272 days, followed by an unmanned period of 394 days, when the computer kept things going. The computer was turned off for 4 years while NASA discussed reboosting Skylab to a higher orbit, or letting it reenter. At the end of 4 years, the onboard computer was booted up by ground command, and the updates worked fine. Skylab was in orbit until 1979, when it reentered the atmosphere, and landed in the ocean near Western Australia.

The Skylab 2 / Crew 1 Command Module is at the Naval Aviation Museum, Pensacola, Florida. Skylab 3 / Crew 2 Command Module is at the NASA Visitor Center at Great Lakes Science Center, Cleveland, Ohio. Skylab 4 / Crew 3 Command Module is at the National Air and Space Museum, Washington, D.C. The service modules were jettisoned before the capsules reentered the atmosphere.

The Skylab at the Smithsonian is the functional flight spare unit. The active unit reentered the atmosphere in 1979. Two pieces were recovered and are on display. The museum in Esperance, Western Australia, has some pieces, as does the Alabama Space & Rocket Center Museum.

## **Spacelab**

The Spacelab program involved reusable modules that flew on the Space Shuttle. These were large laboratories, that could be entered from the Shuttle main deck via the airlock and a tunnel. Spacelabs flew on 32 missions, and did science in microgravity. The European space agency was a major user of the Spacelab service. Besides the habitable lab module, there could also be pallets of instruments also in the Shuttle's cargo bay.

There were two habitable modules built, LM1and LM2. The LM1 can be seen at the Udvar-Hazy Center of the Smithsonian Air and Space Museum, behind the Space Shuttle Discovery. LM2 is on display in the Bremenhalle exhibition at the Airport in Bremen, Germany.

A Spacelab Pallet was transferred to the Swiss Museum of Transport in Lucerne for permanent display on 5 March 2010. The Pallet was flown on the eight-day STS-46 mission, in 1992. The NASA/Italian Space Agency Tethered Satellite System (TSS-1) was carried on the pallet.

## **Orion**

The Orion capsule is the next generation manned space flight unit, designed to hold four astronauts. A mockup of the capsule is at the Kennedy Visitor's Center. It looks like an expanded Apollo Capsule. It is an exploration vehicle designed to carry 4 Astronauts for extended missions. At this writing, it has made an unmanned test flight, Expedition Test Flight-1. It is awaiting a new generation of launch vehicle, the Ares Space Launch System (SLS) to be able to carry out its mission of manned exploration beyond low Earth orbit. The capsule is known as the Crew Exploration Vehicle, which is larger but weighs less than its Apollo predecessor. There is a Service module with propulsion and expendables, like the Apollo design. For lunar missions, the Lunar Surface Access module would be launched separately, and rendezvous with the command and service module in orbit. The manned portion is

designed for 21 days of active time for the crew, plus an additional 6 months quiescent time. Good for the Moon, maybe an asteroid mission, not quite for Mars. An additional piece, the Deep Space Habitat is in the planning stage.

## **Space Shuttles**

The Space Transportation System (STS) was a manned launch and recovery system for spacecraft, that used rocket propulsion to achieve orbit, and glided back to Earth to land on a run-way. A major advantage of the Shuttle system was, when it carried a spacecraft to orbit, it could check to see if it survived the harsh launch environment. If not, the Shuttle could bring it home. Perhaps its major achievement was to repair the Hubble Space Telescope in orbit over several missions. The Shuttle was instrumental in assembling the International Space Station.

At launch, the STS consisted of the winged Shuttle vehicle, a large liquid fuel and oxidizer external tank, and two solid rocket boosters. The solid rocket casings were retrieved from the ocean, and refurbished and reused. The external tanks were not recovered, and were targeted away from shipping lanes in the Pacific and Indian oceans.

There was a mockup, a prototype, and five flight units of the shuttle. Two of the flight units were destroyed, one at launch, one at reentry, with loss of crew.

You probably won't get to go inside, but if you enter the hatch, you are on the lower deck, and the toilet is just to your right. Climb the ladder to the flight deck. In orbit, the cargo bay doors are open, the expose large radiators to space, for cooling purposes. The "arm" is controlled from the back of the upper deck, with windows for visibility.

*Pathfinder*, a full-size mockup, is at the Alabama Space and Rocket Center, Huntsville, AL. OV-101 *Enterprise*, a prototype used for

flight tests in the atmosphere, is at the Intrepid Sea, Air & Space Museum in New York City. OV-102 *Columbia* was destroyed (with loss of crew) in a re-entry accident on February 1, 2003. OV-099 *Challenger* was destroyed (with loss of crew) in a launch accident, January 28, 1986. Debris was recovered and is stored, sealed in an old missile silo, at Cape Canaveral Air Station, FL. OV-103 *Discovery* rests in the National Air and Space Museum, Steven F. Udvar-Hazy Center, Chantilly, VA. (near Dulles Airport). OV-104 *Atlantis* may be seen at the Kennedy Space Center, Cape Canaveral, FL. OV-105 Endeavor is at the Samuel Oschin Pavilion of the California Science Center in Los Angeles, CA.

No flown external tanks have survived, but unused ET-94 is in Los Angeles and will be on display with Space Shuttle Endeavor at the California Science Center, when the Samuel Oschin Air and Space Center opens in 2018. Three external tanks were in manufacturing when the Shuttle Program ended, numbers ET-139-141.

## ***Shuttle Carrier Aircraft***

A Shuttle Carrier aircraft, a specially adapted Boeing 747, can be seen at Palmdale (CA)'s Joe Davis Heritage Airpark. NASA retains ownership of the aircraft. The other carrier aircraft was placed at Space Center Houston, with a Shuttle mockup on top.

## ***USAF Manned Orbiting Laboratory***

The Air Force's Manned Orbiting Lab (1963) was to be launched into orbit, and then two astronauts could visit it via a Gemini Capsule. Mission duration of up to 40 days were envisioned. Hardware was built, but the mission was never flown. There were to be seven flights, 5 of them manned. MOL astronauts in three groups were chosen from Air Force, Navy, and Marine Corps Personnel. The project was canceled in 1969 before any flights were made. NASA's Skylab mission was the follow-on to a manned lab in orbit.

A Gemini-B Capsule for MOL can be seen at the U.S. Air Force

Museum, Dayton, Ohio It has a circular hatch in the heat shield to allow astronauts to enter the MOL from the capsule.

## ***Space Station (ISS)***

An ISS model is at the National Air and Space Museum in Washington, D. C. The station is huge, and designed to operate in zero gravity, so a complete model is not feasible.

There is also a small model of the facility hanging in the Goddard Visitor's Center. The best one to see is at the Marshall Space Flight Center in Huntsville, AL. It is a walk-thru. I forget where the toilet is, but it's much nicer than the one on the Shuttle.

## ***Where can I see a Moon Rock?***

The National Museum of National History (Smithsonian) in Washington, D. C. and the Visitor's Center at Kennedy Space Center in Florida have moon rocks. The guy with the red pick-up truck outside the gate will sell you one...

## ***Where can I see a launch?***

NASA uses several launch sites, and you can view them from a safe yet spectacular location. Before you go, don't assume the launch will take place at the appointed time. During pre-flight check-out, many problems are discovered that lead to delays. The launch will probably not occur at the posted time, or even week. Plan to be flexible.

Kennedy Space Center in Florida is still the go-to location for launches. Try to get there for one of the spectacular night launches. There is a designated viewing area.

I was told that one must watch out for alligators in that area, but I don't know if that's rare or true. I do know that mosquitoes frequent the area, looking for fresh blood, as it were. There is also no shade. Minor matters, when there is a launch to see. Again, check the on-line schedule. Launches from KSC head to the East, out over the

ocean. They can generally be seen from a large area up and down the coast from KSC. A large area to the east is cleared on the ocean and in the sky prior to scheduled launches.

Wallops Flight Center, at Wallops Island, Virginia, launches balloon payloads, sounding rockets, and some ISS resupply missions. They have a designated visitor's viewing area, but launches can be seen from the beach, up and down the coast. As with Kennedy, perhaps worse, are the mosquitoes. They will gladly accept your blood donation. Wallops launches East, over the Atlantic. You can download the WFF ap, and have an online schedule of events. Some night missions release chemicals into the upper atmosphere that produce controlled light shows much like the Aurora.

Vandenburg Air Force Base in Lompoc, California,a is the launch site for Polar orbiting missions. They launch south. The Air Force lets NASA and Space-X use the facility, but it is an active military installation. It is also the site of the California SpacePort, a commercial facility. It does not have a mosquito problem, but people have been killed off the beach by Great White Sharks. Vandenberg has one of its launch pads on the National Registry of Historic Places.

There are regular tours, currently, the third Tuesday of every month at 1 p.m. For thirty people, first-come, first served. It is possible to make advanced arrangements – see their website.

## ***The X-planes, Wings into Space***

There were a series of NASA/ Air Force Projects involving the experimental X-planes, which could fly to the edge of space. This started with the Bell X-1 rocket plane, and continued through the X-57. The X-30 was supposed to be single-stage-to-orbit capable. The X-15's were used in astronaut training, and for studies of re-entry of what was to become the Space shuttle. It was the first aircraft capable of sub-orbital flight. Most of the testing was done at Edwards Air Force Base in California.

## X-15

The X-15 was a manned hypersonic rocket-powered aircraft, designed to fly to the edge of space. You could earn your astronaut badge in an X-15. The international standard is 100 km or 62 miles. The USAF uses the more liberal 50 miles. There were 13 flights greater than 50 miles, and two greater than 62 miles. Both flights to “space” were made by Joseph A. Walker in 1963. The X-15 was carried to altitude under the wing on a B-52 Mothership. After it was released, its rocket engine was ignited, pushing it up out of most of the atmosphere. There were no air-breathing engines. It did a “dead-stick” landing. There were two flight to the 100 km altitude, both by Joseph A. Walker in 1963. The X-15 flights were USAF, U.S. Navy, and NASA sponsored.

The X-15 holds the official world's record to the highest speed recorded by a manned, powered aircraft 4,250 mph (Mach 6.7) at 102,100 feet altitude. That was in 1967. It is officially the world's first space plane.

The X-15 was developed from a concept by Walter Dornbeger for NACA in 1954. He was one of the captured German scientists that formed the core of the rocket team. Dornberger served as the military officer in charge of the German rocket program, and he came to the U.S. With von Braun.

The X-15 operated in two distinct domains, and had both aerodynamic control surfaces, and rocket thrusters. The plane included a pilot ejection seat, usable up to Mach 4, and 120,000 feet. The main engines were dual *Reaction Motors* XLR11 units, using alcohol and liquid oxygen to achieve a total of 16,000 pounds of thrust. Earlier, a single XLR11 pushed the Bell X-1 to be the first aircraft to exceed the speed of sound (Mach1). Later, the X-15 was fitted with the upgraded XLR99 for 57,000 pounds of thrust. Over 175 flights were made in that configuration. Three X-15's made a total of 199 test flights, the last in 1968. Twelve pilots flew the planes, including future astronaut Neil Armstrong, who would go on to become the first man on the moon.

There are two flight models on display:

X-15A-1 (AF Serial No. 56-6670) is on display in the National Air and Space Museum "Milestones of Flight" gallery, in Washington, D.C.

X-15A-2 (AF Serial No. 56-6671) is at the National Museum of the United States Air Force, at Wright-Patterson Air Force Base, near Dayton, Ohio. The aircraft is displayed in the museum's Research and Development Gallery alongside other "X-planes", including the Bell X-1B and Douglas X-3 Stiletto.

There are three mock-ups on display, one at Dryden Flight Research Center, Edwards AFB, California, United States, AF Serial No. 56-6672. Another is at Pima Air & Space Museum, adjacent to Davis-Monthan AFB, Tucson, Arizona, AF Serial No. 56-6671. The third is at Evergreen Aviation & Space Museum, McMinnville, Oregon, with AF Serial No. 56-6672. A full-scale wooden mockup of the X-15 is displayed along with one of the rocket engines.

There are two B-52 Stratofortress mother ships, that carried the X-15's to altitude. NB-52A (AF Serial No. 52-0003) is displayed at the Pima Air & Space Museum adjacent to Davis-Monthan AFB in Tucson, Arizona. It launched the X-15-1 30 times, the X-15-2, 11 times, and the X-15-3 31 times. NB-52B (AF Serial No. 52-0008) is on permanent display outside the north gate of Edwards AFB, California. It launched the majority of X-15 flights.

## **V-2 launch site**

What got Space flight kicked off in the United States is the capture at the end of World War-II of the German Von Braun Team, and a lot of V-2 missiles and parts. Initially, the Team was placed at the Redstone Arsenal an Army facility in Huntsville, Alabama. That would eventually become the current Marshall Space Flight Center. Launches were conducted from the Army's White Sands facility in New Mexico. White Sands is also a National Park, and is

adjacent to Holloman Air Force Base.

The first purpose-built commercial Spaceport is also in New Mexico. The SpacePort America facilities are currently being used by the commercial company, Virgin Galactic.

There is an Army installation at White Sands, as well as a NASA facility for testing rockets. The White Sands Space Harbor was the primary training area for Shuttle Pilots. White Sands also hosts one of several Tracking and Data Relay Satellite Systems (TDRSS) Ground Stations.

White Sands was also the location of Trinity Site, where the first atomic bomb was detonated. Tours are available twice a year. More than seventy years after the test, residual radiation at the site is about ten times higher than normal background radiation in the area. The site is considered a National Historic Landmark.

The New Mexico Museum of Space History in Alamogordo is a great place to visit. This is the area that Dr. Robert Goddard came to when the Fire Marshall kicked him out of Massachusetts for launching rockets. It includes the International Space Hall of Fame, and is the burial site for Ham, the first primate in space, May 1961. Ham lead the way for our astronauts to voyage into the unknown.

The museum has a varied collection, including a rocket sled, a Little Joe-2 rocket, an X-37, a rocket display with sound, a moon rock, and replicas of The Soviet Sputnik, and the U.S. Explorer, the number 1 and 2 satellites in orbit.

## **In conclusion**

There are many legacy and operating locations for the U. S. past and ongoing Space Efforts. I hope this book will be useful to you for visiting the locations, and locating what you are interested in. It will be obsolete when published, so always check the latest information on the internet. I hope my next edition of this book

will discuss support for our base on Mars.

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(current locations of Apollo hardware)
- <http://nasacolumbiamuseum.com/>
- Wikipedia

## Glossary

ABMA – Army Ballistic Missile Agency, Redstone Arsenal, Huntsville, Alabama.

AF – (U.S.) Air Force

AFB – Air Force Base

AGC – Apollo Guidance Computer

AIAA – American Institute of Aeronautics and Astronautics.

AOMC – Army Ordnance Missile Command – 1958

Apogee – farthest point in the orbit from the Earth.

ASC –Advanced Spacecraft Computer, by IBM, for Titan launch

vehicle.

ASIN – Amazon Standard Inventory Number

ARPA – Advanced Research projects Agency.

Astrionics – electronics for space flight.

BP – boilerplate. Mechanical model.

CEV - Crew Exploration Vehicle, part of Orion.

Cyrogenic – very low temperatures.

Dead-stick landing – landing without propulsion. Generally, “get it right the first time”

DoD – (U. S.) Department of Defense.

DTM – dynamic test model, for structural tests.

ET – external tank (Shuttle)

EVA – Extra-vehicular Activity

Gimbal – pivoted support, allowing rotation about 1 axis.

Gpm – gallons per minute.

GSFC – NASA Goddard Space Flight Center, Greenbelt, MD.

Gyro – device to measure angular rate.

H1 – Rocketdyne engine, used on Saturn-I first stage.

ICBM – Intercontinental Ballistic Missile.

IRBM – Intermediate Range Ballistic Missile.

ISBN – International Standard Book Number

ISP – specific impulse. Measure of efficiency of rocket engine.

Units of seconds.

IU – Instrument Unit, Saturn guidance computer.

IUS – Interim upper stage, Internal upper stage – dual upper stage

booster for Shuttle payloads

JPL – Jet Propulsion Laboratory, Pasadena, CA.

JSC – Johnson Space Center, Houston, Texas.

Jupiter – ICBM, 3-stage. Developed by von Braun Team.

Karman line – 100 km above the Earth's surface. The official definition of “space.”

Kev – kilo electron volts, measure of energy of a particle.

KSC – NASA Kennedy Space Center, launch site, Florida.

Lbf – pounds, force.

LC-37 – Launch Complex – 37 at KSC.

LEM – lunar excursion module.

LEO – low Earth orbit.

LES – Apollo Launch Escape System.

Lox – liquid oxygen, boils at -297 F.

LRO – Lunar Reconnaissance Orbit. Ongoing lunar mapping and imaging mission.

LVDA – Launch Vehicle Data Adapter, Saturn

LVDC – Launch Vehicle Digital Computer, Saturn

Mev – million electron volts, measure of energy of a particle.

MINITRACK – “Minimum Trackable Satellite “ U. S. satellite tracking network, 1957.

MOL – USAF Manned Orbiting Lab

MPCV – Multi-Purpose Crew Vehicle (NASA's Orion).

Mph – miles per hour.

MSC – Manned Space Center, Houston, TX. Renamed JSC.

MSFC – NASA Marshall Space Flight Center, Huntsville, AL.

m/s – meters per second.

NACA – National Advisory Committee for Aeronautics, a precursor to NASA.

NASA – National Aeronautics and Space Administration.

NORAD – North American Air Defense (Command) USAF

OV – orbiting vehicle

Perigee – closest point in the orbit from the Earth.

POGO – oscillation in liquid-fueled rocket motors that can lead to failure.

R&D – research & development.

Redstone – Army missile developed by the von Braun team. Used for Mercury manned flights.

Redstone Arsenal – Army R&D facility in Huntsville, AL. Later hosted NASA-MSFC

RP-1 – rocket propellant one, highly refined kerosene.

SA – X – Saturn-Apollo – flight X.

S-IV – second stage of Saturn 1 rocket.

SLS – Space Launch System – NASA next generation launch vehicle.

Sounding rocket – a smaller vehicle, usually sub-orbital, to take “soundings” of the atmosphere.

STADAN – Space Tracking and Data Acquisition Network.

STS – Space Transportation System (Space Shuttle)

Titan – ICBM and NASA/USAF launch vehicle.

TM – Technical Manual.

TTV – towed test vehicle, Gemini capsule with Rogollo kite for soft landing.

Ullage – residual fuel or oxidizer in a tank after engine burn is complete.

USAF – United States Air Force.

UT – Universal time.

V-2 – German World War-II missile developed by the von Braun Team.

WSMR – White Sands Missile Range, New Mexico. U. S. Army Facility

X-plane – experimental, X-1 to X-31

X-15- experimental rocket-powered aircraft.

X-20 Dyna-Soar Project

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